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The dependence of fish community structure and dynamics on floodplain and riparian ecotone zone in Parana River, Brazil

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Abstract

Flood intensity was a main factor determining access to the riparian/floodplain ecotonal resources of the upper Parana River, Brazil, and in consequence determining yield of the dominant trophic groups, which are fish feeding on flooded grasslands and on riparian fruits and leaves. Prey and predator density both declined in years of low floods, and predators did not recover until the next year of high flood, more slowly than in the case prey fish, most probably due to differences in life cycle length. The life cycle of one of the most important species, Curimba (*Prochilodus lineatus* – Characidae) depends on access to the floodplain lagoons and return to the reservoir after maturation for intensive growth. The riparian/floodplain habitat complexity and connectivity has great significance for fish community dynamics and fisheries yield, and may serve a reason to create a national park in the last floodplain section of the upper Parana River.

Introduction

The dependence of fish yield in large river systems on floodplain habitats is a well known phenomenon (Welcomme, 1979), but there have been few in-depth analyses of the ecological affinity of fish species for different types of floodplain and ecotonal habitats (Schiemer & Spindler, 1989).

The floodplain and riparian zone of the tropical river Parana has been an integral part of the ecosystem, determining to a great extent the dynamics of its fish communities (Agostinho *et al.*, 1993).

The construction of dams started early this century, reduced much of the fluvial habitat to a less diversified lentic environment, which has been reflected in the fish community (Agostinho *et al.*, 1994). The dams have obstructed migration of some commercially valuable fish species (*Pseudoplatystoma corruscans* – Pimelodidae, *Salminus maxillosus* – Characidae) in upper part of this river, seriously reducing its fisheries yield (Lowe-McConnell, 1987).

Another, even more important factor, which reduces biodiversity and productivity of fish communities is the decline of diversity of land/water ecotones due to the deforestation of the floodplain, and much of the reservoir shoreline. It influences fish communities directly by reducing the terrestrial food supply and the spawning and rearing substrate. Recently, some attempts have been made by the management of the Itaipu Binacional to reforest the Brazilian shore of the reservoir, to reduce land erosion and increase biodiversity of terrestrial and aquatic habitats (Muller & Zelazowski, 1989).

This paper presents preliminary results of studies on the dependence of fish communities in the Parana River on riparian/floodplain ecotone resources, for the maintenance of their diversity. The data form the background for the possible creation of a National Park Reserve in the last floodplain part of the upper Parana River.

Study area

The Parana River extends over 809 km in Brazilian territory, of which only 500 km is running water. In 1995 a new dam will be closed at Porto Primavera, further restricting the flowing stretch to only 200 km. Finally, in about 2010, the planned Ilha Grande dam

project starting just above the Itaipu reservoir, will destroy the last lotic segment of this river in Brazil.

Sites were studied in the lower part of this stretch, including its free course, its floodplain and Itaipu reservoir. Fourteen stations, situated in different environments, including rivers (4 stations), floodplain channels (3), floodplain pools (4) and the reservoir (3), were investigated through two years (Fig. 1). The mesotrophic Itaipu Reservoir (Surehma, 1989) closed in 1982, has an area of 1460 km^2, is 151 km long and has a maximum depth of 170 m (mean 21.5 m). Its turnover time is 40 days. Its upper border covered the Sete Quedas Falls that was a barrier for fish migration upstream and delimited two ichthyological provinces (Bonneto, 1986).

Materials and methods

Standardized catches (CPUE = number or biomass / 1000 m^2 gillnets) were made from October 1986 to September 1988 by 10 gillnets (20.0 m × 2.0 m) of stretched mesh sizes ranging from 3.0 to 16.0 cm, operated during 24 hours a month/station.

All fishes were measured immediately after transport to the field laboratory. body, gonads and gut content were weighed in the field and stomach contents were preserved in formalin and investigated in the laboratory.

The fishes were classified in three trophic groups on the basis of the predominant food: aquatic (planktivores, benthivores, piscivores, part of insectivores); iliophagous (*aufwuchs* and mud eating); and ecotonal (foraging in flooded areas on fruits, leaves and insects falling into the water – including detritivores, herbivores, part of omnivores, and some insectivores). Stomach contents were analyzed by the methods described by Hyslop (1980), and detailed in Hahn (1991).

Results

Shift in community structure as an effect of river impoundment

Itaipu has been one of the biggest reservoirs in the world, situated below that section of the diversified floodplain of the Parana River where it is an almost natural tropical river. This has had a positive effect on the fish community biodiversity and especially on maintenance of the migratory species of great commercial value, such as Curimba (*Prochilodus lineatus* – Prochilodontidae), whose different life stages utilize floodplain habitats, but when mature became an important fisheries resource in the reservoir. Probably due to the permanent connection of the reservoir with the floodplain, several other migratory species which were expected to disappear at impoundment, still occur in the reservoir and are an important component of the fisheries yield (Agostinho *et al.*, 1994).

Despite this connection, during the first six years after the dam was closed, the species richness fell from 113 (ITAIPU BINACIONAL, 1979) to only 83. The two commercially valuable species of Characidae in the riverine fishery, both fructivorous – *Piaractus mesopotamicus* and *Brycon orbignyanus*, were completely eliminated. What is more important, only one of the ten most frequently collected species in the river remains among the main species in the reservoir (Agostinho *et al.*, 1994), namely *Plagioscion squamosissimus* – Sciaenidae, which was not native, but introduced in to the Parana in 1967 (Cruz *et al.*, 1990).

The density of the planktivorous *Hypophthalmus edentatus* – Hypophthalmidae increased sharply after conversion of the lotic habitat into the lentic (Fig. 2). The second dominant was the insectivorous *Auchenipterus nuchalis* – Auchenipteridae a species of short life span and internal fertilization.

The mud feeders were reduced severely in proportion from 57% to 8–20% (Hahn, 1991) and replaced in the reservoir by insectivores. Predators still remain the most important group as before impoundment, but their species composition (19) has changed. The main predators of commercial value are: jau – *Paulicea luetkeni* (Pimelodidae), barbado – *Pinirampus pirinampu* (Pimelodidae) and curvina - *Plagioscion squamosissimus*. Dourado-cachorro - *Rhaphiodon vulpinus* (Cynodontidae) is also frequent but less important as are piranha – *Serrasalmus marginatus* (Serrasalmidae) which fishermen consider as 'pest' species. The ichthyocoenosis is still changing under the strong influence of floods above the reservoir.

Much more drastic changes in fish community composition are expected after 2010, when the Reservoir Ilha Grande floods the last big section of natural floodplain of the Parana.

Effect of flood intensity on fish community dynamics

Access to the various floodplain habitats has been very variable from year to year depending on flood inten-

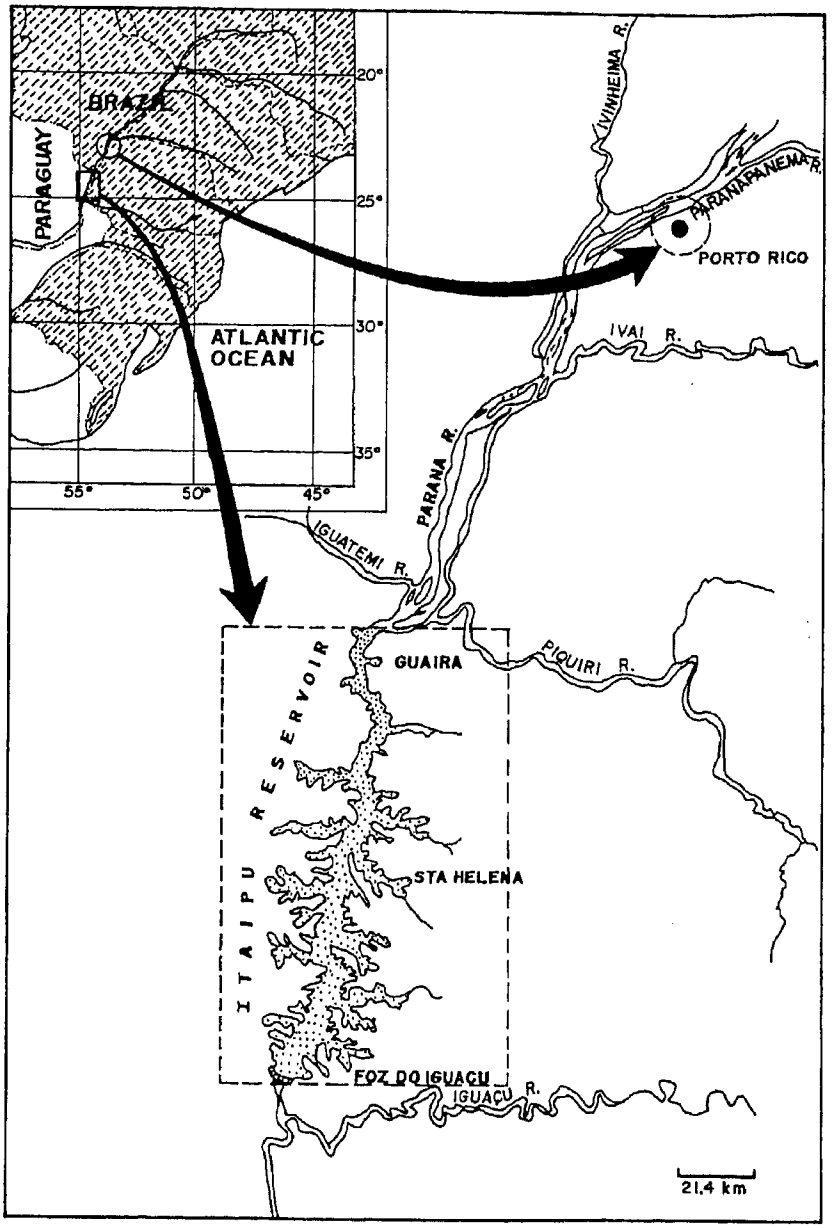

Fig. 1. The map of the upper Parana River and Itaipu Reservoir. The areas of most intensive research are the floodplain in the Porto Rico region and Itaipu Reservoir.

sity. The fish statistics data from years of differing flood intensity suggest a long term effect of preventing access to the floodplain ecotone on the fish community (Fig. 3). During autumn 1987, when the flood was very low, the density of prey fish declined much more than in a year of normal flood (1988), probably due to intense predator pressure at their migration in the main channel and to higher efficiency of the fisheries. In the year of normal flow the main factors increasing mortality in autumn were increasing hydrological

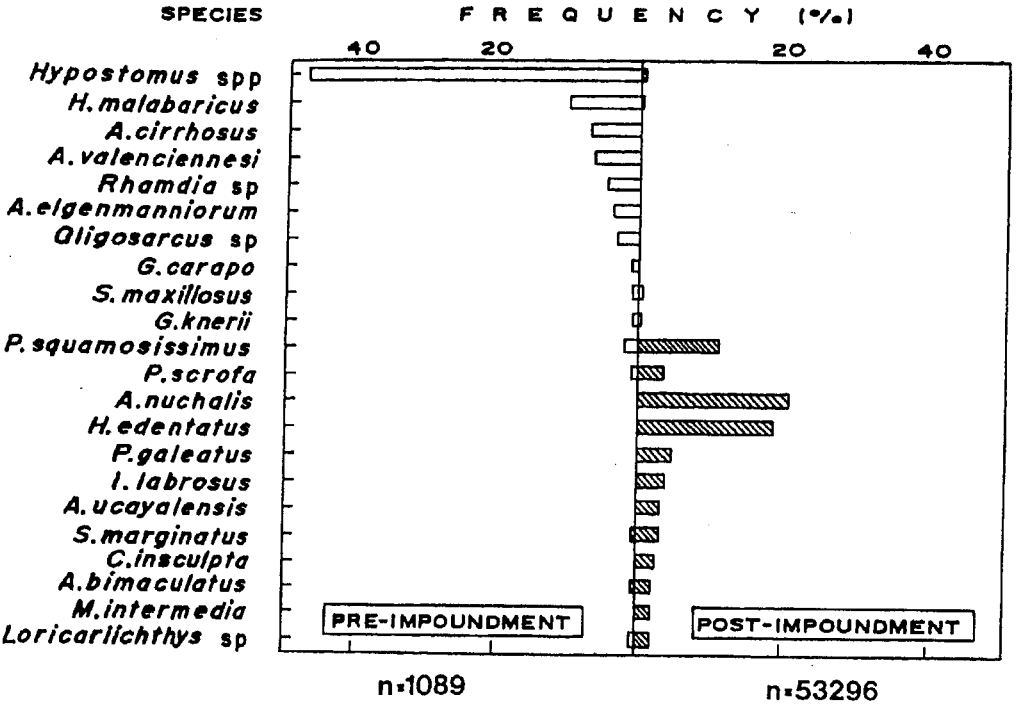

Fig. 2. The shift in fish community structure (main species) as an effect of impoundment of Itaipu Reservoir (after Agostinho *et al.*, 1994).

stress – declining water level, decreasing temperature and declining oxygen level.

The biomass of prey fish started to rise immediately after the high flood in 1988, possibly due to high prey survival in the diversified floodplain habitats. The situation was different for predatory fish. In the year of low flood their density also declined sharply, probably due to high efficiency of the fishing at the mouth of the floodplain channels where predators are especially concentrated when preying on fish descending from the drying floodplain. In such a situation of high concentration, cannibalism may increase significantly. In 1988, when the flood occurred, predator biomass achieved only half of that of 1987. This difference in the pattern of predator and prey density fluctuation might be a result of differences in the life cycle length. Predators are usually larger and mature later, than prey fish. However, the different pattern of dispersion during and after low and high floods might influence these patterns. Those preliminary observations need further profound studies.

The floodplain connection and fish life cycle

Riverine fishes in all types of climate are adapted to use optimal habitats at different stages of ontogeny (Northcote, 1978; Thorpe, 1988). That is why the floodplain connection is an important factor in the maintenance of at least some species in the river system as for example curimba in the Parana River (Fig. 4). Juvenile fish, up to the time of their first maturation at age 2 (L2) live in floodplain lagoons. Then they migrate on the high flood via the anastomosing floodplain channels to the main river and finally downstream to the reservoir. The flood's intensity determining access to the marginal habitats, is critical for a successful life cycle and thus for high fish yield. During low flood years most fertile floodplain lagoons are isolated from the river system and curimba yield may be reduced by the lack of the access to their optimal habitat and declining water level in the lagoons, which expose trapped fish to piscivorous birds and other predators. High mortality of trapped fish also occurs through desiccation. The

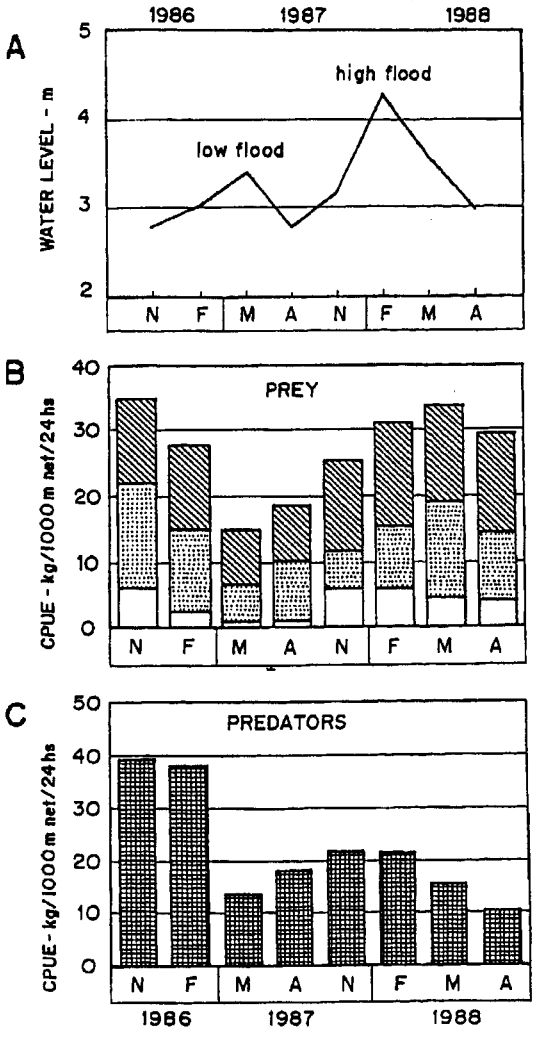

Fig. 3. Changes in density of fish of different trophic groups from floodplain habitats at upper Parana River, coincident with different flood levels: A. Changes in annual average water level in 1987 and 1988; B. Catchability of the nonpredatory trophic groups (prey) on the low flood in 1987 and the high in 1988 (see text for explanation) □ -aquatic; ▤ -iliophagous (floodedgrass + *aufwuchs*); ▧ -ecotonal (terrestrial); C. Decline in predatory fish biomass in the year after the low flood 1987. CPUE = catch per unit effort expressed as fish biomass by 1000 m^2 of gillnets at 24 hours. ($n_{86-87} = 15{,}737$; $n_{87-88} = 17{,}079$).

loss of fish biomass has been evaluated to be approximately four times that of the of professional fisheries (Bonetto *et al.*, 1969).

The importance of ecotonal food resources in the different types of habitats

To evaluate the importance of the land/water ecotones as habitats and sources of food for fish in the Parana River, its floodplain and Itaipu Reservoir, the occurrence of the main trophic groups have been analyzed by CPUE (Fig. 5). The combined data from the years of low and high flood demonstrate that highest CPUE occurred in lagoons and channels. The fish biomass was highest in the main river channel, but the density of all four groups increased proportionally from reservoir to river, to channels, and to the lagoons, with the biggest increase among fish feeding directly on ecotonal resources (fruits and leaves) and on flooded grasslands (iliophagous). This finding is consistent with the assumption that marginal ecotonal habitats are important rearing places where, under good trophic conditions, juvenile fish of all feeding groups may avoid predators, which are the main component of the fish assemblage in the river. In consequence the reduction of floodplain connection and/or the degradation of the riparian ecotone structure may lead to drastic reduction of the diversity of the fish community and its productivity within the whole Brazilian segment of the Parana River system.

Discussion

In tropical floodplain rivers, where the fish fauna is most diverse, the largest fraction of fish communities relies on floodplain ecotone resources (Lowe-McConnell, 1987). Recent progress in understanding ecological processes in floodplain rivers (Junk *et al.*, 1989) and acceleration of damming, canalization and deforestation in floodplains create the necessity for more insight into the dynamics of the top trophic levels-fish in these old aquatic ecosystems. These human impacts modify the hydrological regime and habitat complexity for fish along the whole river continuum. Schiemer and Zalewski (1992) distinguished a hierarchy of factors dependent on riparian/floodplain zone complexities for fish. In the diverse natural river environment, the most common compensatory response to both abiotic and biotic stresses, particularly severe on the early development stages, has been migration (Zalewski & Naiman, 1985). That component of the riverine system which compensates most for environmental harshness and provides suitable habitat is the floodplain and riparian zone. The steady reduction

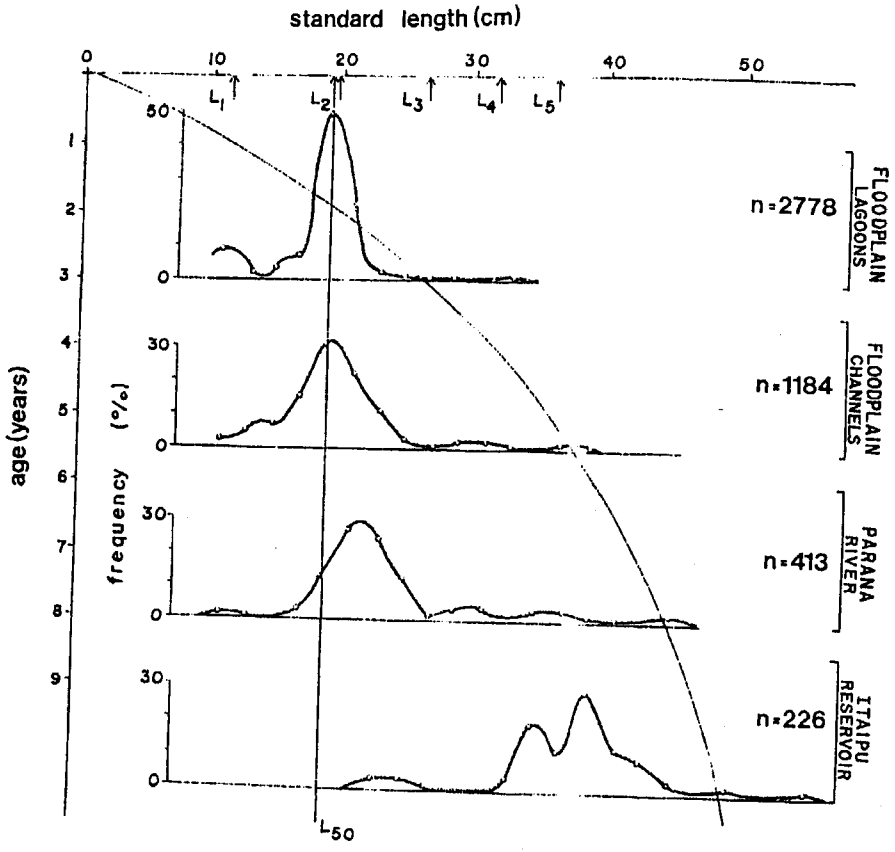

Fig. 4. The life cycle of curimba (*Prochilodus scrofa*) in different types of habitats in the middle Parana River, presented as a change in frequency distribution in different habitats. The first maturation (L50) and growth curve are superimposed on the frequency diagram (after Agostinho *et al.*, 1993).

of this zone reduces seriously biodiversity and quality/quantity of fish yield. This is because, in tropical rivers, fish dependent on the riparian zone for food are a significant percentage of fish communities, and because those fish are themselves important in the predators' diet. In consequence reduction in their occurrence will decrease the commercially important fisheries yield in the upper Parana River of dourado (Characiformes) and pintado (Siluriformes).

In the Plata River basin, Quiros & Baigun (1985) demonstrated that abundance of fish community, composed similarly as in the upper Parana, mainly by iliophagous and detritivorous species, the fish abundance is correlated with amount of organic matter in water column. In turn the complexity of the land/water ecotonal zone (floodplain) is the main source of the organic matter for the river (Junk *et al.*, 1989).

In north-eastern Brazilian reservoirs, the highest fish yield occurs if the number of predators is between 2 and 4 (Pinto Paiva *et al.*, 1994). Probably fish yield in Itaipu could be significantly increased by reducing the 19 predatory species here.

At this region some preimpoundment studies were done (Merona, 1985) and some evaluation of the early effect of closing river by dam on downstream fish communities (Merona, Carvalho & Bittencourt, 1987).

The high vulnerability of some riverine fish species to habitat modifications is mostly due to their complicated life cycle and this may be exaggerated by intensive exploitation. The life cycle of curimba is strictly dependent on the existence of a diverse floodplain above the reservoir. Hence future development plans threaten to eliminate this species and to reduce biodiversity and productivity of fish communities seriously. Further conversion of floodplain wetlands into

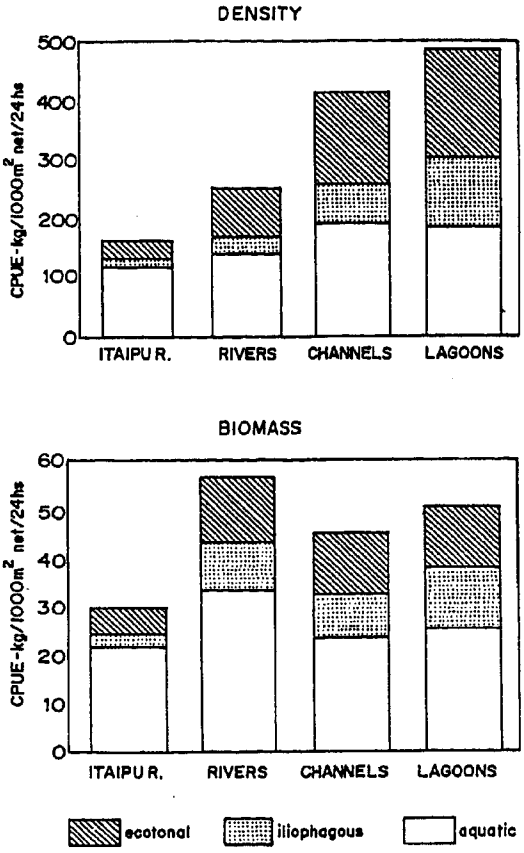

Fig. 5. The gradual increase of fish density along the habitat gradient, with increasing heterogeneity of ecotones. CPUE is catch per unit effort expressed as fish number or biomass by 1000 m^2 of gillnets at 24 hours($n_{Itaipu\ R} = 18\ 069$; $n_{rivers} = 4,107$; $n_{channels} = 10,363$; $n_{lagoons} = 18,346$).

pasture land, and then dam construction in 2010 above Itaipu reservoir will destroy the last floodplain section of the Parana River. Global changes of the climate may reduce further the flood intensities in this region.

For efficient protective measures to maintain the diverse fish fauna of the middle Parana River, more quantitative data on dependence of fish on ecotonal floodplain and riparian habitat is necessary. Such data will be background for the long term strategy of restoration and management of land/inland water ecotones in the last floodplain section of the Parana River.

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